

# City of New Braunfels Low Impact Development Manual

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*2016*



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## **1 Introduction**

The New Braunfels Low Impact Development (LID) Manual serves to supplement the detailed information that the Drainage and Erosion Control Design Manual (DCM) provides with a guide to best practices for low impact development. The Engineering Division will review all plans submitted with the intent to follow the best practices in this manual and will be approved on a case by case basis.

### **1.1 Purpose and Scope**

The purpose of the New Braunfels LID Manual is to establish standard practices for the planned design of low impact storm drainage, erosion control, and water quality facilities within the City of New Braunfels, Texas and its extraterritorial jurisdiction (ETJ). This manual is intended to serve as a guideline for the design of low impact developments and LID features. Responsibility for actual design remains with the design engineer.

The DCM and the City of New Braunfels Code of Ordinances contain requirements for the design of storm drainage, flood protection, water quality, and erosion control facilities. Where there is any conflict between this manual and the current code, the code shall take precedence.

Should conflicts occur between policy and criteria in this manual versus other regulatory authorities with jurisdiction in the same area, such as Texas Commission on Environmental Quality (TCEQ) or Texas Department of Transportation (TxDOT), then the more stringent requirement will apply and the designer will need to show how both requirements have been met.

Any design element not specifically addressed in this document or City Code of Ordinances shall be designed in accordance with the following or other method approved by the Engineering Division:

- A. San Antonio River Basin Low Impact Development Technical Guidance Manual (San Antonio River Authority); and
- B. Watershed Stewardship for the Edwards Aquifer Region, A Low Impact Development Manual (Greater Edwards Aquifer Alliance).

### **1.2 Maintenance**

Maintenance of the LID, best management practices (BMPs), and water quality features is required to maintain and meet the specified design criteria for flow rate, volume and water quality control functions. If not maintained properly, effectiveness can be reduced, resulting in water quality impacts. The design professional shall provide a maintenance schedule and requirements with the construction documents and final as-built plans. Deferred maintenance could result in detrimental effects on the landscape and increased potential for water quality reduction and localized flooding. The City has the right to conduct periodic inspections of privately owned and maintained drainage and water quality improvements to ensure that the maintenance schedule is being implemented.

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## 2 Non-structural Practices

Non-structural practices are often the first step in implementing Low Impact Development. These involve many planning and site design practices such as keeping existing trees on-site, minimizing compaction of soil that inhibits water infiltration, and planting trees and other vegetation in areas where none exists. Once developing on a given site, non-structural practices include simple tools such as disconnection of impervious cover, all of which are discussed in this section.

These non-structural practices can:

- Lower a project cost, by reducing elements such as street length and width;
- Increase project yield, by creating more space for development compared with conventional designs; and
- Often require no-cost strategies such as disconnecting a downspout.

One effect of these practices is to reduce the volume of runoff, thereby reducing the size of conveyance systems as well as flood control structures. Consequently, these practices should be implemented to the maximum extent possible consistent with local code. This section will present several non-structural processes that sites, whether new development or re-development, should examine first. These include items such as a conducting a site assessment or strategies for site layout. It will then follow with guidelines to reduce the impact of the development, including reductions in impervious cover or two different disconnection strategies.

### 2.1 Sustainable Site Design

Sustainable site design incorporates approaches to new and redevelopment projects which reduce impacts on watersheds by conserving natural areas, and better integrating stormwater treatment. The aim of sustainable site design is to reduce the environmental “footprint” of the site while retaining and enhancing the owner/developer’s purpose and vision for the site. Many of the sustainable site design concepts employ non-structural on-site treatment that can reduce the cost of infrastructure while maintaining or even increasing the value of the property relative to conventional designed developments.

The goals of sustainable site design include:

- Prevent stormwater impacts rather than having to mitigate for them;
- Manage stormwater (quantity and quality) as close to the source as possible and minimize the use of large or regional collection and conveyance;
- Preserve natural areas, healthy soils, native vegetation and reduce the impact on watershed hydrology;
- Use natural drainage pathways as a framework for site design;
- Reduce soil compaction during construction to maintain infiltration capacities of the soil;
- Minimize the amount of disturbance to existing, mature stands of vegetation;

- Utilize simple, non-structural methods for stormwater management that are lower cost and lower maintenance than structural controls;
- Create a multifunctional landscape which considers construction and maintenance implications; and
- Use appropriate plant species and communities for the eco-region and the designed media.

The first series of stormwater site design practices and techniques can be grouped into Preservation of Natural Features and Conservation Design. For more in-depth guidance on sustainable site design, please see the Sustainable Sites Initiative website ([www.sustainablesites.org](http://www.sustainablesites.org)).

### **2.1.1 Preservation of Natural Areas**

Preservation of natural features includes techniques to foster the identification and preservation of natural areas that can be used in the protection of water resources. Whether a large contiguous area is set aside as a preservation zone or certain smaller areas have been identified as appropriate for preservation, protecting established vegetation (existing trees, shrubs, grasses and other flora) can help reduce re-vegetation requirements, reduce long-term erosion, preserve habitat, protect water and land resources, and maintain a healthy ecosystem.

Other benefits include:

- An immediate finished “aesthetic” that does not require time to establish;
- Increased stormwater infiltration due to the ability of mature vegetation to process higher quantities of stormwater runoff than newly seeded areas;
- Reduced runoff velocity, quantity and erosion rates (by intercepting rainfall, promoting infiltration, and lowering the water table through transpiration among others);
- Provides a buffer against noise and visual disturbance during construction;
- Provides fully developed habitat for wildlife;
- Reduced construction costs; and
- Usually requires less maintenance (e.g., irrigation, fertilizer) and land clearing labor and costs than planting new vegetation.

In order to reach these benefits, it is important to first identify and preserve sensitive areas that affect hydrology. A site assessment is the process whereby the design team conducts an in-depth evaluation of the overall environmental conditions of the proposed development or redevelopment prior to detailed site design. Natural conservation areas are typically identified using mapping and field reconnaissance assessments. Areas proposed for protection should be delineated early in the planning stage, long before any site design, clearing or construction begins.

The goal is to broadly identify and evaluate the ecological systems influencing the area to reduce cost and time impacts from a design, construction and maintenance prospective. Achieving cost reductions is a direct result of a solid understanding of environmental characteristics and integrating the most appropriate construction. The initial design and planning phase is the most appropriate time to conduct

the site inventory. For a project which will include LID in New Braunfels, items to examine during a site assessment should include:

- Soil types and infiltration rates;
- Health and types of existing vegetation (trees, grasses, shrubs and forbs);
- Land use history and historical vegetation pre-settlement;
- Riparian areas and significant waterways;
- Prominent landforms;
- Site drainage patterns;
- Potential pollution sources;
- Floodplains; and aquifer zones; and
- Any and all karst features including caves or sinkholes.

Identifying these areas can help inform later development as sites should be located to avoid sensitive resource areas such as floodplains, steep slopes, erodible soils, wetlands, mature forests and critical habitat areas. Buildings, roadways, and parking areas should be located to fit the terrain and in areas that will create the least impact.

### ***Floodplains and Floodways***

Development in floodplains and floodways can reduce the ability of the floodplain and floodway to convey stormwater, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties. Ideally, the entire 100-year full build out floodplain and Federal Emergency Management Agency (FEMA)-approved floodway should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state. Future development should remain out of all floodplain and the floodway, even in areas where development has already occurred.

Once identified, preservation areas should then be incorporated into site development plans and clearly marked on all construction and grading plans to ensure that construction activities are kept out of these areas and that native vegetation is kept in an undisturbed state. The boundaries of each conservation area should be mapped by carefully determining the limit that should not be crossed by construction activity.

### ***Slopes***

Development on slopes with a grade of 15 percent (7:1) or greater should be avoided to limit soil loss, erosion, excessive stormwater runoff, and the degradation of surface water. Excessive grading should be avoided on all slopes, as should the flattening of hills and ridges. Steep slopes should be kept in an undisturbed natural condition to help stabilize hillsides and soils. On slopes greater than 25 percent (4:1), no development, re-grading, or stripping of vegetation should be allowed. Developer should prepare a slope map as part of the site development plans showing greater than 25 percent slopes and restricting that area from development.

### ***Soils***

Areas of a site with hydrologic soils, such as sands and sandy loam soils should be conserved and these areas are ideal to be incorporated into undisturbed natural or open space areas. Conversely, buildings and other impervious surfaces should be located on those portions of the site with the least permeable soils. Similarly, areas on a site with highly erodible or unstable soils should be avoided for land disturbing activities and buildings to prevent erosion and sedimentation problems as well as potential future structural problems. These areas should be left in an undisturbed and vegetated condition.

### ***Buffers***

A riparian buffer is a special type of natural conservation area along a stream, wetland or shoreline where development is restricted or prohibited. The primary function of buffers is to protect and physically separate these water bodies from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management functions, can act as a right of way during floods, and can sustain the integrity of water resource ecosystems and habitats.

Riparian buffers should be continuous and not interrupted by impervious areas that would allow stormwater to concentrate and flow into the stream without first flowing through the buffer. Existing forested riparian buffers should be maintained. Where no wooded buffer exists, reforestation should be considered. Proper restoration should include all layers of the forest plant community, including trees, understory, shrubs and groundcover.

The buffer width needed to perform properly will depend on the size of the stream and the surrounding conditions, but a minimum 25-foot undisturbed vegetative buffer is needed for water bodies draining less than 40 acres but 5 or more acres. This first 25-foot section should be a zero development zone and should contain restrictions on the types of the uses and vegetation in this zone. Beyond the 25-foot section, an additional 50-foot or larger undisturbed buffer is ideal. Additional zones can be added to extend the total buffer to at least 100 feet from the edge of the stream. Some streams and watersheds may benefit from additional measures to ensure adequate protection. In some areas, specific state laws or local ordinances already require stricter buffers than are described here. The following buffer sizes are determined by catchment area:

- Streams draining 640 acres (one square mile) or greater should have a minimum buffer of 300 feet from the centerline on each side of the stream.
- Streams draining less than 640 acres but 320 or more acres should have a minimum buffer of 200 feet from the centerline on each side of the stream.
- Streams draining less than 320 acres but 128 or more acres should have a minimum buffer of 100 feet from the centerline on each side of the stream.
- Streams or swales draining less than 128 acres but 40 or more acres should have a minimum buffer of 50 feet from the centerline on each side of the drainage.
- Streams or swales draining less than 40 acres but 5 or more acres should have a minimum buffer of 25 feet from the centerline on each side of the drainage.

The development of LID features within the buffer zone should be allowed within the 25-75 foot buffer zone as long as the development does not adversely impact the riparian area.

Development within the larger riparian buffer (beyond 50') should be limited only to those structures and facilities that are absolutely necessary. Such limited development should be specifically identified in any codes or ordinances enabling the buffers. When construction activities do occur within the riparian corridor, specific mitigation measures should be taken, such as deeper buffers or riparian buffer improvements.

Buffers should remain in their natural state. However, some maintenance is periodically necessary, such as:

- Planting to minimize concentrated flow;
- Removal of invasive or exotic plant species when these species are detrimental to the vegetated buffer; and
- Removal of diseased or damaged trees.

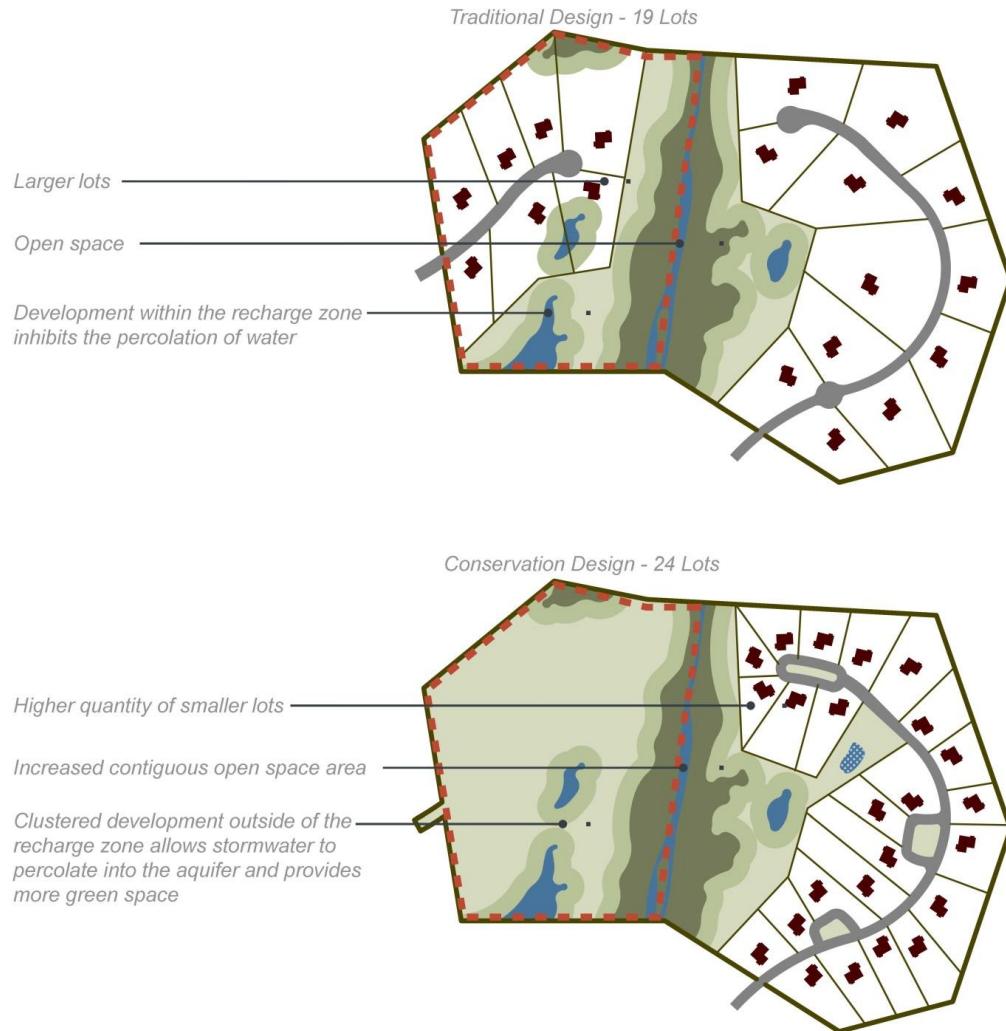
#### ***Construction and Maintenance Considerations***

Once a site is under construction, minimal disturbance methods should be used to limit the amount of clearing and grading that takes place on a development site, preserving the undisturbed vegetation and natural hydrology of a site. A limit of disturbance (LOD) should be established based on the maximum disturbance zone. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils. LOD distances may vary by type of development, size of lot or site, and by the specific development feature involved. A Limit of Development line should be shown on the site development plans.

Not only should these natural conservation areas be protected during construction, but they should also be managed after occupancy by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, conservation areas are protected by legally enforceable deed restrictions, conservation easements and a maintenance agreement.

#### **2.1.2 Conservation Design**

For the purposes of this document, traditional design can be viewed as the style of suburban development that has evolved over the past 50 years and generally involves larger lot development, clearing and grading of significant portions of a site, wider streets and larger cul-de-sacs, enclosed drainage systems for stormwater conveyance, and large “hole-in-the-ground” detention basins (see Figure 2-1).



**Figure 2-1 – Traditional and Conservation Design**

Conservation design, also known as open space design or cluster development, includes laying out the elements of a development project in such a way that the site design takes advantage of a site's natural features, preserves the more sensitive areas, and identifies any site constraints and opportunities to prevent or reduce impacts. Techniques include:

- Preservation of undisturbed areas;
- Preservation of stream buffers;
- Reduction in clearing and grading;
- Locating projects in less sensitive areas; and
- Clustering development.

These natural conservation areas are typically identified through a site assessment. Depending on the site, an assessment can be performed by professionals on the project development team (engineers,

landscape architects or planners for example); however, to fully examine a site and its ecological conditions which will influence BMP design, more in-depth site analysis should be done by hydrologists, ecologists, biologists or others professionals with site assessment experience in order to test infiltration rates, assess soil type and quality, and be able to properly identify existing vegetation. In many cases, a geotechnical report may also be required to assess depth to groundwater among other factors. When done before the concept plan phase, the planned conservation areas, and identification of other sensitive features also outlined above, can then be used to guide the layout of a project. For more guidance on conducting a site assessment, visit the Sustainable Sites Initiative™ guidelines.

Conservation subdivisions typically incorporate smaller lot sizes to reduce overall impervious over while providing more undisturbed open space and protection of water resources. This approach concentrates structures and impervious surfaces in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. Typically smaller lots and/or nontraditional lot designs are used to cluster development and create more conservation areas on the site.

Conservation developments have many benefits compared with conventional commercial developments or residential subdivisions. They can reduce:

- Impervious cover;
- Stormwater pollution;
- Construction costs; and
- Need for grading and landscaping, while providing for the conservation of natural areas.

Along with reduced imperviousness, which carries multiple ancillary benefits as mentioned above, conservation designs provide a host of other environmental benefits lacking in most conventional designs. They can prevent encroachment on conservation and buffer areas. They create communitywide interconnected network of protected meadows, fields and woodlands. They can help to provide habitat, and protect farmland and other natural resources while allowing for the maximum number of residences undercurrent community zoning. As less land is cleared during the construction process, alteration of the natural hydrology and the potential for soil erosion are also greatly diminished. Perhaps most importantly, open space design reserves 25 to 50 percent of the development site in conservation areas that would not otherwise be protected.

Conservation developments can also be significantly less expensive to build than conventional projects. Most of the cost savings are due to reduced infrastructure cost for roads and stormwater management controls and conveyances. Further, developers find that these properties often command higher prices than those in more conventional developments. Several studies estimate that residential properties in open space developments garner premiums that are higher than conventional subdivisions and moreover, sell or lease at increased rates.

Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the conservation

areas are protected by legally enforceable deed restrictions, conservation easements and maintenance agreements.

Preservation of natural areas and conservation designs can help to preserve predevelopment hydrology of the site and aid in reducing stormwater runoff and pollutant load. Undisturbed vegetated areas also promote soil stabilization and provide for filtering and infiltration of runoff. Maintaining existing vegetation can be particularly beneficial to sites with floodplains, wetlands, stream banks, steep slopes, critical environmental features, or where erosion controls are difficult to establish, install or maintain.

## **2.2 Reduction in Impervious Cover**

Once a development or redevelopment site has completed a site assessment to identify all the features mentioned above and the initial planning and design phase has begun, there are several additional non-structural LID tools to implement: reduce total impervious cover and disconnect.

Reduction of impervious cover includes methods to reduce the amount of rooftops, parking lots, roadways, sidewalks and other surfaces that do not allow rainfall to infiltrate into the soil, in order to reduce the volume of stormwater runoff, increase groundwater recharge, and reduce pollutant loadings that are generated from a site.

Most municipalities agree that an increase in impervious cover will increase runoff. However, the degree to which this is true is a function of several factors such as soil type, rainfall intensity, flow path and the amount of connected impervious cover among others. Thus, the effectiveness of disconnection practices – directing gutter downspouts into vegetated areas or disconnecting pavement – can be difficult to quantify. Therefore, many municipalities may not give any credit for these types of activities, even though there is obviously some benefit. The following section describes methods to disconnect existing or proposed impervious areas to maximize the benefit of LID. If at any time the City requires a maximum impervious coverage percentage by land use, then this BMP should apply if the impervious coverage percentage is at least 5 percent below the maximum.

## **2.3 Disconnection**

Disconnection of impervious surfaces and downspouts is encouraged to maximize the function of the LID practices. Disconnection is a low-cost, effective non-structural control which can reduce total runoff volume, increase the time of concentration and promote infiltration. The first step in disconnection is to identify the source of runoff and understand how it will be managed once disconnection occurs. In addition, well-conceived use of disconnection methods can reduce overall project costs by reducing or eliminating the need for more expensive structural practices.

### **2.3.1 Impervious Cover Disconnection**

Although the amount of impervious cover on a site can be minimized, it is unrealistic to think it can be eliminated completely. Despite this, impervious areas do not necessarily have to contribute to the runoff leaving the site. The amount of runoff and associated pollutants from a project can be reduced by disconnecting impervious surfaces. By disconnecting impervious areas and directing the flow to infiltration basins or designated buffer areas, a portion of additional runoff that would contribute to

stormwater runoff is infiltrated close to the source instead. Further, the runoff that would potentially carry pollutants from the site to surface water instead gets treated and helps recharge groundwater.

Disconnection methods should be incorporated at the planning and design level. However, the designer and reviewer should note that these methods must be used in concert with the design of other stormwater conveyance and treatment practices. The use of these disconnection methods does not relieve the designer or reviewer from following the standard engineering practices associated with safe conveyance of stormwater runoff and good drainage design.

### **2.3.2 Downspout Disconnection**

Rooftops with exterior drains for the gutter (the normal configuration for most residential structures) are one of the easiest disconnection practices to implement. These downspouts should be directed to landscaped portions of the site rather than driveways or sidewalks unless the driveway is constructed of pervious paving materials as shown in Figure 2-2. It is not common, but driveways can be crowned so that a portion of the runoff is directed to vegetated areas, rather than the street.



**Figure 2-2 – Pervious Pavers**

In addition to directing downspouts to vegetated areas, roof runoff may also be directed to cisterns and other rain barrels for later consumption, or even to depressed storage or other underground storage areas. Further, this runoff may be directed through a treatment train system as described below and demonstrated in Figure 2-3.

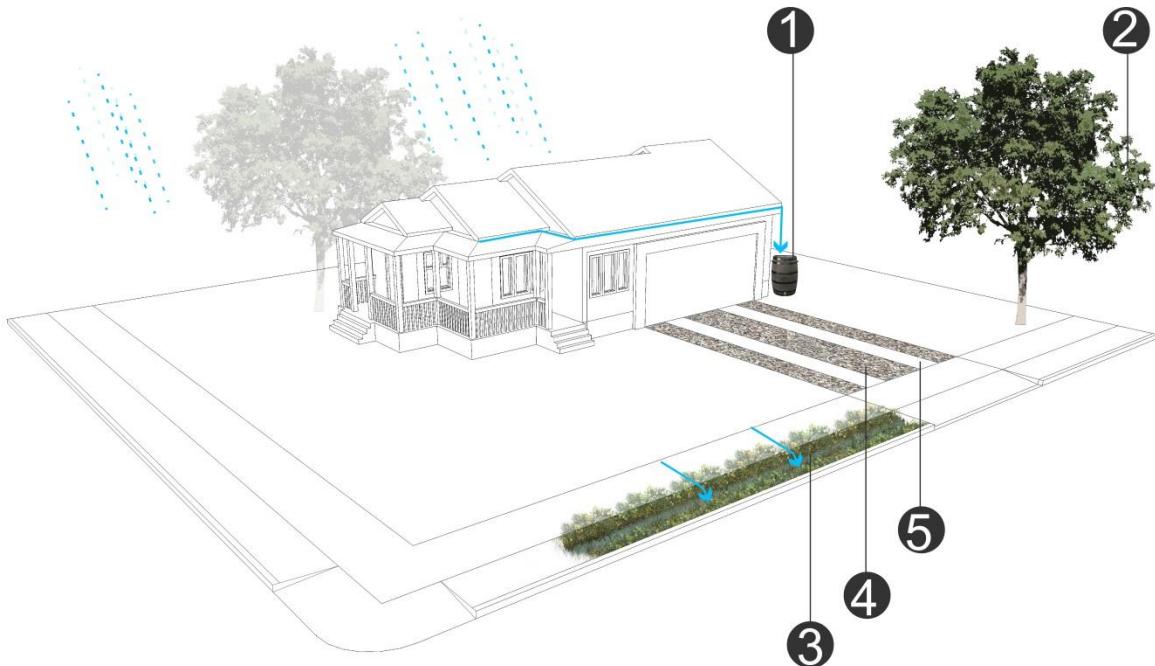


Figure 2-3 – Treatment Train System

1. *Capture and Use: Captures and stores runoff from impervious surfaces, reducing volume and overall water quality impairments. Typically used for irrigation.*
2. *Preserve Native Vegetation: Enhances the aesthetic quality of community and maintains infiltration and evapotranspiration rates.*
3. *Vegetated Swale: Channels that slow stormwater runoff and promote infiltration, trap sediment and help treat pollutants.*
4. *Pervious Pavement: Pavement that allows rain to infiltrate, thereby reducing runoff and promoting groundwater recharge.*
5. *Reduced Hardscape: Narrower streets, sidewalks and driveways increase pervious areas and open spaces.*

Some design considerations include:

- Slowing down the water after it leaves the downspout if the volume and velocity are high;
- Keeping the disconnected runoff away (10' minimum) from other impervious surfaces to reduce the chance for re-connection;
- Not placing the disconnected runoff into a steep slope area which could cause erosion and concentrate flows; and
- Directing the runoff into features specifically designed to receive (and either store, soak, treat or convey) this runoff.

## 3 Structural Practices

The following sections describe a variety of structural LID practices that can be used to convey, treat and infiltrate stormwater runoff. This section will describe the following practices:

- Rain Gardens & Bioretention
- Vegetated Swales
- Vegetated Filter Strips
- Porous Pavement
- Rainwater Harvesting

In order for LID practices to perform effectively basic guidelines need to be followed in their design, construction and maintenance. This section is written to guide professionals through the design process. Descriptions are provided for the full suite of LID practices appropriate for the New Braunfels area. However, technical guidance will not be provided as there are many different ways to achieve the intended outcome, and this appendix serves only as a guide. Lastly, this section discusses several other structural controls in brief – green roofs, constructed wetlands and proprietary systems – and provides links to resources for more information if projects in the New Braunfels region wish to implement these practices.

### 3.1 Description and Selection Criteria

Though the LID toolbox is unlimited, this manual focuses on the above structural tools as they are most appropriate for the New Braunfels region. Further, many of these practices are most effective at reducing both runoff volume and pollutant loads. A quick summary of the selection criteria, described in detail throughout this section, is provided in Table 3-1.

Table 3-1 – Low Impact Development Best Management Practices General Benefits, Maintenance and Costs

LID BMP	Benefit	Maintenance	Cost
<b>Bioretention and Rain Gardens</b>	Slows runoff, filters pollutants, can detain or retain runoff, provides for ET, has numerous water quality benefits, and the design is flexible	Low to High depending on location and design	Low to High depending on location and design
<b>Vegetated Swales</b>	Slows runoff, conveys runoff and provides some filtration, detains water, provides some water quality and ET benefit	Low	Low to Medium
<b>Vegetated Filter Strip</b>	Slows runoff, provides some filtration, detains water, provides pollutant removal and ET benefit	Low	Low
<b>Porous Pavement</b>	Slows runoff and provides some filtration, detains or retains water depending on design, provides for evaporation	Low	High
<b>Rainwater Harvesting</b>	Provides some water quality benefit because it captures the first flush, detains and retains water, water conservation, runoff volume reduction	Low	Medium to High

### 3.2 Rain Gardens and Bioretention

The rain garden and bioretention best management practices function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological and chemical treatment processes. These facilities normally consist of a filtration bed, ponding area, organic or mulch layer, and plants. Figure 3-1 illustrates the basic components of the system.



**Figure 3-1 – Basic Rain Garden Components**

Rain gardens and bioretention systems are very similar BMPs in their design and function. Both systems can be used in any land use type or for any site. For the purposes of this manual, the main difference between the two systems is that a bioretention system uses engineered soils. Engineered soil refers to the bioretention planting media which has been modified from its original condition or is a specialized, pre-determined mix of materials. While rain gardens do not include engineered soils, they can include slightly modified soils. Both systems can be designed with or without underdrains or liners.

### **3.2.1 Description**

A rain garden is a landscaped area in a basin shape designed to capture runoff and settle and filter out sediment and pollutants, primarily from rooftops, driveways, sidewalks, parking lots and streets. Swales with check dams or berms that allow water to back up behind them function like rain gardens, and flow-through planters have also been described as a series, or treatment train, of rain gardens. What they all have in common is that they allow water to be retained in an area with plants and soil where the water is allowed to pass through the plant roots and the soil column.

In general, there are two kinds of rain gardens. Filtration rain gardens cleanse and detain stormwater runoff. Because they are specifically lined or have an underdrain to prevent infiltration in some areas (in areas where the influent is deemed too pollutant-heavy or for other site constraints) they do not significantly reduce stormwater volumes. However, these systems still provide substantial pollutant removal and increase the time of concentration. Infiltration rain gardens cleanse, detain and reduce runoff volumes by allowing water to seep into the surrounding soils.

Rain gardens are constructed with native soils, rather than the engineered media used in bioretention systems. They are designed with shallow ponding depths that are adjusted to the infiltration capacity of the soil to ensure timely absorption of the water and, as mentioned above, do not always include underdrains in their design. Otherwise, the selection criteria and limitations are the same as bioretention systems.

Bioretention areas are similar to rain gardens except that they contain an engineered media mix. A picture of a bioretention system located in a parking lot island is presented in Figure 3-2.



**Figure 3-2 – Parking Lot Bioretention System**

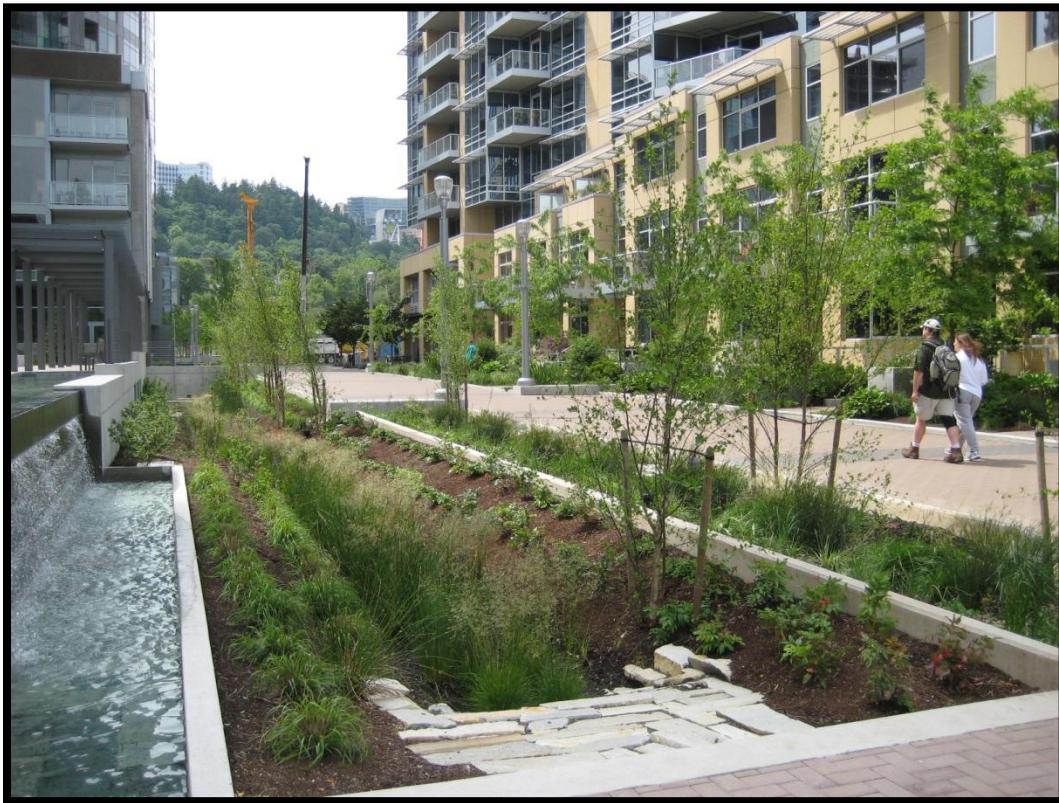
In areas of New Braunfels with thin layers of topsoil over shallow limestone, bioretention could be a lined, more linear filtration system to remove pollutants before being released to streams. This alternative design would be a shallower system with a larger surface area.

Infiltration of the stored water in the bioretention system into the underlying soils occurs over a period of days when installed without an underdrain system. Figure 3-3 shows rain gardens or bioretention systems with no liner or underdrain, where filtered stormwater runoff infiltrates into the surrounding native soils.



**Figure 3-3 – Bioretention System Without an Underdrain System**

Figure 3-4 shows rain garden and Table 3-2 lists a selection of plants that could be used in a rain garden (“Stormwater Management: Rain Gardens”, Texas A&M AgriLife Extension, B-6247). County horticulture extension agents, local horticulturalists, Lady Bird Johnson Wildflower Center, Texas Master Gardeners or local nursery managers can be consulted for further information.



**Figure 3-4 – Rain Garden**

Table 3-2 – Selection of Rain Garden Plants

Botanical Name	Common Name
<b>Perennials</b>	
<i>Achillea millefolium</i>	Yarrow
<i>Acorus calamus</i>	Sweet flag
<i>Alstroemeria pulchella</i>	Peruvian
<i>Aquilegia hinckleyana</i>	Texas columbine
<i>Asclepias tuberosa</i>	Butterfly weed
<i>Aspidistra elatior</i>	Cast iron plant
<i>Amorpha fruticosa</i>	False indigo
<i>Baptisia australis</i>	Blue false indigo
<i>Calyptocarpus vialis</i>	Horseherb
<i>Canna generalis</i>	Canna
<i>Coreopsis verticillata 'Moonbeam'</i>	Moonbean coreopsis
<i>Dichondra argentea 'Silver Falls'</i>	Silver falls
<i>Echinacea purpurea</i>	Purple cone flower
<i>Eupatorium coelestinum</i>	Blue mistflower
<i>Eupatorium purpureum</i>	Joe-Pye weed
<i>Helianthus helianthoides</i>	Ox-eyed sunflower
<i>Hibiscus coccineus</i>	TX Star hibiscus-red
<i>Hibiscus coccineus 'Lone Star'</i>	TX Star hibiscus-white
<i>Hibiscus moscheutos</i>	Swamp rose mallow
<i>Hymenocallis liriosme</i>	Spider lily
<i>Ipomopsis rubra</i>	Standing cypress
<i>Iris spp. bearded and hybrids</i>	Iris
<i>Iris brevicaulis Louisiana species and hybrids</i>	Louisiana iris
<i>Kosteletzky virginica</i>	Marsh mallow
<i>Liatris spicata</i>	Gayfeather
<i>Lobelia cardinalis</i>	Cardinal flower
<i>Lythrum salicaria</i>	Loosestrife
<i>Monarda fistulosa</i>	Bee balm
<i>Rudbeckia hirta</i>	Black-eyed Susan
<i>Rudbeckia fulgida 'Goldstrum'</i>	Black-eyed Susan
<i>Rudbeckia maxima</i>	Giant coneflower
<i>Ruellia brittoniana 'Katie's'</i>	Ruella Katie
<i>Salvia coccinea</i>	Scarlet sage
<i>Setcreasea pallida</i>	PurpleHeart
<i>Sisyrinchium angustifolium</i>	Blue-eyed grass
<i>Solidago altissima</i>	Goldenrod
<i>Stachys byzantine</i>	Lamb's ear
<i>Tradescantia occidentalis</i>	Spiderwort
<i>Vernonia fasciculata</i>	Ironweed
<i>Zephyranthes spp.</i>	Rain lily
<b>Grasses</b>	
<i>Carex spp.</i>	Sedge
<i>Chasmanthium latifolium</i>	Inland sea oats
<i>Muhlenbergia reverchonii</i>	Seep muhly
<i>Panicum virgatum</i>	Switch grass
<b>Shrubs</b>	
<i>Aesculus pavia</i>	Scarlet buckeye
<i>Callicarpa Americana</i>	American beautyberry
<i>Cephalanthus occidentalis</i>	Buttonbush
<i>Clethra alnifolia</i>	Summersweet clethra
<i>Ilex decidua</i>	Possumhaw holly

Botanical Name	Common Name
<i>Ilex vomitoria</i>	Yaupon
<i>Itea virginica</i>	Virginia sweetspire
<i>Leucothoe recemosa</i>	Leucothoe, Sweetbell
<i>Myrica cerifera</i>	Southern wax myrtle
<i>Sabal minor</i>	Dwarf palmetto
<i>Symporicarpos orbiculatus</i>	Coralberry
<i>Spirea x bumalda 'Anthony Waterer'</i>	Anthony water spirea
<b>Trees</b>	
<i>Acer rubrum var. drummondii</i>	Southern swamp maple
<i>Betula nigra</i>	River birch
<i>Cyrilla racemiflora</i>	Leatherwood (Titi)
<i>Magnolia virginiana</i>	Sweet bay magnolia
<i>Sophora affinis</i>	Eve's necklace
<i>Taxodium distichum</i>	Bald cypress

### 3.2.2 Selection Criteria

#### *Benefits*

- Good choice of an on-site system serving a relatively small drainage area, since it can be incorporated into the site landscaping;
- Provides stormwater treatment that enhances the quality of downstream water bodies by infiltrating runoff, or when designed with liner or underdrain, temporarily storing runoff and releasing it over a period of days to the receiving water;
- The vegetation provides shade and wind breaks, and absorbs noise;
- Improves an area's landscape and has many aesthetic benefits;
- Easily integrated into site landscaping; and
- Their design can be formal or informal in character.

One advantage to rain gardens is that these are slightly simpler systems that can be easily implemented without the need for special training making them a good BMP for homeowners or property owners to implement on their own property.

#### *Limitations*

- Can be difficult in areas with slopes greater than 20 percent (5:1). Bioretention systems need to be level for optimal filtration so in locations with slopes greater than 20 percent (5:1), they should be terraced. One option of an alternative design for these areas would be to construct a series of bioretention systems in a terraced design with check dams at regular intervals;
- Can be difficult where mature tree removal would be required since clogging may result, particularly if the facility receives runoff with high sediment loads;
- Unlined systems are not suitable at locations where the water table is within 6 feet of the ground surface and where the surrounding soil stratum is unstable; and

- Inclusion of substantial amounts of compost in the filter media can substantially increase nutrients in the discharge. Organic matter needs to be used in limited amounts and of high-quality, low-nutrient composition.

### ***Cost Considerations***

The major costs associated with bioretention systems are the soil mixture and plants. The costs are greater than those for landscaping alone; however, the water quality benefits are substantial. The use of underdrains and liners will add to the cost versus bioretention systems designed for infiltration. An additional cost-benefit is received when bioretention or rain garden features double as traffic calming devices, such as a street bump-out.

#### **3.2.3 Rain Garden Design Considerations**

Rain gardens provide both sedimentation and filtration of stormwater, and infiltration when no underdrain is used. While sedimentation and filtration will occur throughout the entire surface area of the rain garden, the majority of sedimentation occurs in the immediate area of runoff entry.

#### **3.2.4 Bioretention Design Considerations**

Bioretention facilities are effectively sand filters that include additional organic and soil material in the filtration media to support vegetation. This allows these facilities to be integrated into the site landscaping where they can provide unobtrusive treatment of stormwater runoff.

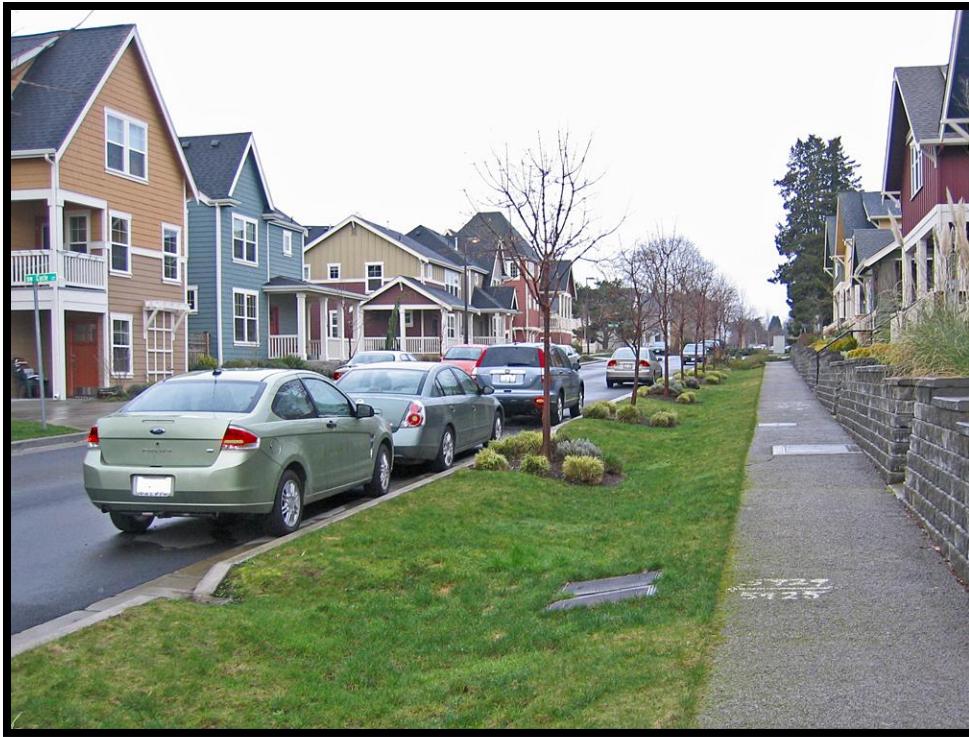
For bioretention design specifications, plant selection considerations and recommended maintenance, refer to the TCEQ manual “Technical Guidance on Best Management Practices.”

### **3.3 Vegetated Swales**

#### **3.3.1 Description**

Grassy swales are vegetated channels that convey stormwater and remove pollutants by sedimentation and infiltration through soil. They require shallow slopes and soils that drain well. Pollutant removal capability is related to channel dimensions, longitudinal slope and amount of vegetation. Optimum design of these components will increase contact time of runoff through the swale and improve pollutant removal rates.

Grassy swales are primarily stormwater conveyance systems. They can provide sufficient control under light to moderate runoff conditions, but their ability to control large storms is limited. Therefore, they are most applicable in low to moderate sloped areas or along highway medians as an alternative to ditches and curb and gutter drainage. Grassy swales can be used as a pretreatment measure for other downstream facilities, such as bioretention areas. Enhanced grassy swales utilize engineered soils and an underdrain to provide filtration of pollutants. A picture of a grassy swale is presented in Figure 3-5.



**Figure 3-5 – Vegetated Swale**

Swales can be more aesthetically pleasing than concrete or rock-lined drainage systems and are generally less expensive to construct and maintain. Swales can slightly reduce impervious area and reduce the pollutant accumulation and delivery associated with curbs and gutters. The disadvantages of this technique include the possibility of erosion and channelization over time, and the need for more ROW than a storm drain system.

### **3.3.2 Selection Criteria**

When choosing to implement swales, it is important to note that swales are limited to treating only a few acres and there must be sufficient land area available in order for these features to function properly.

#### ***Benefits***

- Pretreatment for other LID practices; and
- Availability of water during dry periods to maintain vegetation.

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, and dimensions and slope of the swale system. In general, swales can be used to convey runoff from areas of less than 2 acres, with slopes no greater than 5 percent (20:1). Research in the Central Texas area indicates that vegetated controls are effective at removing pollutants even when dormant. Therefore, irrigation is not required to maintain growth during dry periods, but may be necessary only to prevent the vegetation from dying. An example of a parking lot swale is shown in Figure 3-6.



Figure 3-6 – Parking Lot Swales

#### ***Limitations***

- Can be difficult to avoid channelization;
- Cannot be placed on steep slopes; and
- Area required may make infeasible on intensely developed areas.

The topography of the site should permit the design of a channel with appropriate slope and cross-sectional area. Site topography may also dictate the need for additional structural controls since the maximum recommended longitudinal slope is about 2.5 percent (40:1). Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipation and grade check. Steep slopes also can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes infiltration.

#### ***Cost Considerations***

A swale is a lower-cost, alternate form of conveyance that provides some treatment and so has both a cost benefit and a water quality benefit when compared with curbs and gutter or pipe drainage systems. Enhanced swale systems will cost more than a grassy swale due to the addition of certain components for enhanced treatment capacity.

#### ***3.3.3 Design Guidance***

A grassy swale is a sloped, vegetated channel or ditch that provides both conveyance and water quality treatment of stormwater runoff. Pollutant removal occurs through the processes of particle settling, adsorption, and biological uptake that occur when runoff flows over and through vegetated areas. There are two options available for swale design, the basic swale and the enhanced swale. For vegetated swale design specifications, plant selection and maintenance, refer to the TCEQ manual “Technical Guidance on Best Management Practices.”

## 3.4 Vegetated Filter Strips

### 3.4.1 Description

Vegetated Filter Strips (VFS), also known as filter strips or vegetated buffer strips, are a moderate to low-cost method for improving the quality of storm water runoff by using biological and chemical processes in soil and vegetation to filter out pollutants from runoff flowing through it as sheet flow. VFS are similar to grassy swales except that they are essentially flat with low, even slopes, and are designed to accept runoff as overland sheet flow only. Formerly common agricultural practices, VFS have now become common practice for treating runoff from roads, highways and other pervious surfaces.

A photograph of a vegetated buffer strip is shown in Figure 3-7. The dense vegetative cover facilitates conventional pollutant removal through sedimentation and infiltration.



Figure 3-7 – Vegetated Buffer Strip

Filter strips cannot treat high velocity flows, and do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels for design storms. This lack of quantity control restricts their use to relatively small tributary areas. While VFS are applicable in many different

areas, there are two primary applications for vegetative filter strips. Roadways and small parking lots are ideal locations where runoff that would otherwise discharge directly to a receiving water body, passes through the filter strip before entering a conveyance system. Properly designed roadway medians and shoulders make effective vegetated filter strips. The second application is land maintained in the natural condition adjacent to perimeter lots in subdivisions that will not drain via gravity to other stormwater treatment systems. The catchment area must have sheet flow to the filter strips without the use of a level spreader. VFS often require a large amount of space relative to other BMPs so they can be restricted in some areas beyond those two examples mentioned above.

Successful performance of filter strips relies heavily on maintaining shallow dispersed flow. If runoff is flowing over the VFS too fast, or in a concentrated manner, it will likely lead to rill erosion or scouring. To avoid flow channelization and maintain performance, a filter strip should:

- Contain dense vegetation with a mix of erosion resistant, soil binding species;
- Engineered vegetated filter strips should be graded to a uniform, even and a slope of less than 20 percent (5:1);
- Natural vegetated filter strip slopes should not exceed 10 percent (10:1) on average, providing that there are no flow concentrating areas on the strip; and
- Laterally traverse the contributing runoff area.

Filter strips can be used upgradient from watercourses, wetlands or other water bodies, along toes and tops of slopes, and at outlets of other stormwater management structures. The most important criteria for selection and use of this BMP are space and slope.

### **3.4.2 Selection Criteria**

When implementing VFS, it is important to make sure that sufficient space is available and that the slope of the VFS is less than 20 percent (5:1).

#### ***Benefits***

- Soils and moisture are adequate to grow relatively dense vegetative stands; and
- Comparable performance to more expensive structural controls.

#### ***Limitations***

- Can be difficult to maintain sheet flow (there is a tendency to form rills or gullies);
- Cannot be placed on steep slopes;
- Area required may make infeasible on some sites; and
- Poor soils which cannot sustain a grass cover crop.

#### ***Cost Considerations***

Filter strips are one of the least expensive stormwater treatment options and cost less to construct than curb and gutter drainage systems. This is one reason why they are often used in conjunction with other stormwater management practices in a treatment train approach.

### 3.4.3 Design Guidance

Filter strips may be natural or engineered. The use of natural filter strips is limited to perimeter lots and other areas that will not drain by gravity to other BMPs on the site. Engineered filter strips achieve an 85 percent TSS removal efficiency in the first 15 percent of the area, and no concentration reduction after that. For vegetated swale design specifications, plant selection and maintenance, refer to the TCEQ manual “Technical Guidance on Best Management Practices”.

## 3.5 Porous Pavement

### 3.5.1 Description

Porous pavements are a special type of pavement that allows rain to pass through it. They can be used on both permeable and impermeable soils and in the latter case are designed with an underdrain system. Where soils are sufficiently permeable all the runoff will infiltrate and no discharge of stormwater or associated pollutants will occur. Systems designed with an underdrain provide substantial pollutant removal and increase the time of concentration, which are substantial benefits even when the volume of runoff is not substantially reduced. TCEQ specifies that porous pavement may only be used in the contributing zone of the Edwards Aquifer Recharge Zone.

There are several types of porous pavement, including porous asphalt, pervious concrete, pavers and grid type systems. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate and water. Pervious concrete has enough void space to allow rapid percolation of liquids through the pavement. Pavers themselves are typically impermeable; however, infiltration occurs either in the gaps between the pavers or within openings cast as part of the geometry of the paver. The use of pavers in a portion of a parking lot is presented in Figure 3-8.



Figure 3-8 – Permeable Pavers Used in Parking Lot

The porous pavement surface is typically placed over a highly permeable layer of open-graded gravel and crushed stone. The void spaces in the aggregate layers act as a storage reservoir for runoff. A filter fabric is placed beneath the gravel and stone layers to screen out fine soil particles. Figure 3-9 illustrates a common porous paver installation and demonstrates the use of the filter fabric between gravel and stone layers.

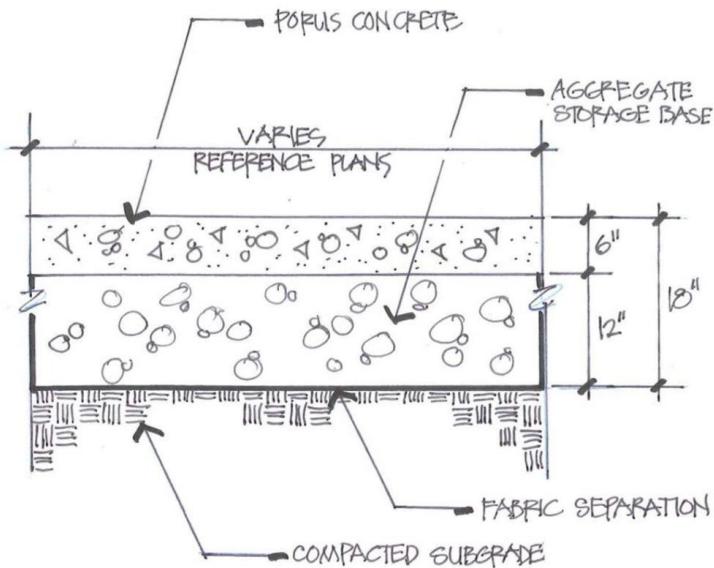


Figure 3-9 – Basic Porous Pavement Installation with Filter Fabric

Two common modifications made in designing porous pavement systems are:

1. Varying the amount of storage in the stone reservoir beneath the pavement; and
2. Adding perforated pipes near the top of the reservoir to discharge excess stormwater after the reservoir has been filled.

Some municipalities have also added stormwater reservoirs (in addition to stone reservoirs) beneath the pavement. These reservoirs should be designed to accommodate runoff from a design storm and should provide for infiltration through the underlying subsoil if an underdrain is not provided.

### **3.5.2 Selection Criteria**

Porous pavement may substitute for conventional pavement on parking areas, areas with light traffic, sidewalks and patios. Slopes should be flat or very gentle. For systems installed without underdrains, soils should have field-verified permeability rates of greater than 0.5 in/hour, and there should be a 4-foot minimum clearance from the bottom of the system to bedrock or the water table.

#### ***Benefits***

The advantages of using porous pavement include:

- Substantial pollutant reduction, even in systems with underdrains with surface discharge;
- Increased time of concentration;
- Less need for curbing and storm sewers; and
- Potential for groundwater recharge.

#### ***Limitations***

The use of porous pavement is constrained, requiring deep permeable soils (in systems without underdrains), low traffic loads, and consideration of impacts to adjacent buildings. Some specific disadvantages of porous pavement include the following:

- Many pavement engineers and contractors lack expertise with this technology;
- Porous pavement has a tendency to become clogged if improperly installed or maintained;
- Porous pavement has a high rate of failure;
- There is some risk of contaminating groundwater, depending on soil conditions and aquifer susceptibility; and
- Fuel may leak from vehicles and toxic chemicals may leach from asphalt and/or binder surface. Porous pavement systems are not designed to treat these pollutants.

#### ***Cost Considerations***

Estimated costs for an average annual maintenance program of a porous pavement parking lot are approximately \$200 per acre per year. This cost assumes four inspections each year with appropriate jet hosing and vacuum sweeping treatments.

### 3.5.3 Design Guidance

Porous pavement systems consist of a pervious surface on top of a stone base, often referred to as the stone reservoir, which stores runoff before it infiltrates into the underlying soil. The use of permeable pavement techniques will be dictated by local or regional regulations but are often allowed in pedestrian areas (sidewalks, patios, plazas) and in some cases, for certain parking areas such as in stalls or overflow areas. For porous pavement design specifications, refer to the Addendum of the TCEQ manual "Technical Guidance on Best Management Practices."

## 3.6 Rainwater Harvesting

Rainwater harvesting - collecting rainwater from impervious surfaces and storing it for later use - is a technique used for millennia. In drought stricken Central Texas and other areas around the country with limited water resources and stormwater pollution concerns, the role that rainwater harvesting can play for water supply is being reassessed for both residential and commercial buildings. Thus, it is important to note that there are current changes being made to local rainwater harvesting laws, and design criteria are often modified, so it is best to check the most current regulations and incentives before implementing this practice.

Rainwater can be stored in a variety of structures. These include small 55 gallon barrels, the most common sizes for residential applications, to large underground cisterns. A photo of a rainwater collection system with a large above-ground storage tank is provided in Figure 3-10. Further, cisterns and barrels can be constructed of many different materials including wood, metal, plastic, glass or synthetic compounds.



**Figure 3-10 – Above-ground Water Storage Cistern**

While potable use is possible for harvested rainwater, necessary on-site treatment and perceived public health concerns will likely limit the quantity of rainwater used for potable demands. Irrigation and the non-potable uses of toilets, urinals and HVAC makeup are currently the most common end uses for harvested rainwater. These are all beneficial uses individually, and when combined, they constitute a significant portion of residential and commercial water demand.

Focusing harvested rainwater on irrigation and selected non-potable indoor uses can significantly lower demand while allowing a balance and public comfort level between municipal potable water and reused rainwater. For harvesting systems to be efficient stormwater retention systems, the collected rainwater needs to be used in a timely manner to ensure maximum storage capacity for subsequent rain events. Cistern systems generally supply uses with significant demands to ensure timely usage of the collected water.

Outreach and education is a critical component of rain barrel programs, because of the more episodic and less structured use of this collected water. Homeowners should be informed of the steps needed to maximize the effectiveness of their rain barrels.

### **3.6.1 Selection Criteria**

#### ***Benefits***

- Contributes to water conservation;
- Augments drinking water supplies;

- Reduces stormwater runoff and pollution;
- Reduces erosion in urban environments; and
- Provides water that needs little treatment for irrigation or non-potable indoor uses.

#### ***Limitations***

- Limited standards or guidelines for rainwater harvesting, especially its use indoors (however, please see the Texas Water Development Board or Comal and Guadalupe counties for guidance);
- Sufficient storage needs to be available to capture subsequent rain events, so the stored water needs to be used relatively rapidly;
- Storage takes up space on small lots; and
- It is difficult for regulators to ensure that these small, dispersed systems are being operated in a way to significantly reduce stormwater runoff.

#### ***Cost Considerations***

The average cost of water delivered by municipal distribution systems is very low, which generally puts rainwater harvesting at a disadvantage compared to potable water when only the economics of water supply are considered. However, when these systems are sufficiently large, they may reduce the size of downstream detention facilities. In areas without water distribution systems and poor groundwater quality, rainwater harvesting may provide the best option for providing high quality water for indoor use.

#### **3.6.2 Design Guidance**

This manual does not provide design guidance for rainwater harvesting as there are a variety of design options available. Further design guidance can be found in with the Texas Water Development Board.

### **3.7 Treatment Trains**

A treatment train consists of a series of stormwater practices installed in series. There are a number of reasons why this type of configuration is preferred. First, implementing a number of practices provides the opportunity to include a variety of unit processes (sedimentation, filtration, biological uptake, etc.) to treat the runoff, which optimizes the pollutant removal. Secondly, the use of multiple systems provides a level of redundancy so that at least partial treatment is being achieved even if one system is not functioning properly.

Probably the biggest benefit is the reduction in maintenance costs that can be achieved by using a dry system, such as a swale, upstream of ponds or other permanently wet facilities. Removal of accumulated sediment, trash, and debris from a dry swale is far easier and less expensive than removal of the same material once it enters a pond.

The configuration for a treatment train can take many different forms. Common applications include the use of a vegetated swale to convey stormwater to or from other treatment systems, such as bioretention cells. Swales can provide some level of pretreatment when installed upstream of other

facilities and can provide the opportunity for some ancillary infiltration even when that is not the primary goal of implementing this practice. Other applications include the treatment train system where disconnected downspouts are directed through a series of additional BMPs. If there is excess runoff at the end of a treatment train system, the treated stormwater could then be connected to the storm sewer or other area. Figure 2-3 provides an example of a treatment train installation. Treatment train systems should be designed with maintenance considerations in mind. This includes items such as reducing velocity and erosion, or potentially adding a litter trap that is shovel width, at the point of entry.

## 3.8 Additional Best Management Practices

Thus far, this section has described five structural LID practices that can be used to convey, treat, and infiltrate stormwater runoff in New Braunfels. Though the LID toolbox is unlimited, this chapter focuses on the above structural tools as they are most appropriate for the New Braunfels region. This last section discusses several other structural controls in brief, including a description of each technique and some important design considerations and limitations to each practice. Other TCEQ-approved BMPs may be used on a case-by-case basis, upon approval of the City Engineer.

### 3.8.1 Green Roofs

Green roofs, also known as vegetated- or eco-roofs, are roofs with a vegetated surface and growing media substrate. Green roofs are typically grouped into two distinct categories: extensive and intensive. Extensive green roofs have a shallower soil media, typically 6" or less, and thus support mainly low-growing ground cover. Intensive green roofs have a deeper amount of substrate (6" or more) and can include a variety of uses and vegetation, including trees. These intensive green roofs also have the appearance of a ground level garden, and thus can require additional investments in plant maintenance. Whether intensive or extensive in design, all green roofs contain, in their simplest design, an insulation layer, a waterproof membrane, a root barrier, a layer of growing medium and vegetation.

#### *Benefits*

Research has shown that green roofs can, if adequately designed, exhibit many benefits, and that these benefits are even more substantial in urban areas such as noise reduction, heating / cooling benefits, improved water quality, habitat provision and runoff volume reductions. With regard to stormwater management, green roofs can prevent or reduce runoff from the lot by capturing it on the rooftop via plants, growing media and other green roof structural features (Oberndorfer et al., 2007). Rainfall soaks into the green roof's media layer, detaining runoff until after peak rainfall, and plants help return this moisture to the atmosphere through evapotranspiration. Of course, depth of media, plant type and regional climatic factors including rainfall patterns all directly affect the amount of runoff delay and reduction. However, studies have consistently shown that there is potential benefit in terms of stormwater management when compared with a conventional roof.

#### *Limitations*

There are several limitations to green roof implementation and most of these limitations depend on the system's design, including each of the components. First, green roofs are expensive LID tools, because

their implementation can require specific media mixes or structural modifications to support the added weight on retrofit projects, and liability concerns among other items. Second, although there has been demonstrated sequestration of potential water pollutants such as nitrates and heavy metals, some research has demonstrated that runoff from green roofs can include increased levels of organic carbon, nitrogen and phosphorus due to leaching from the substrate, particularly if the green roof substrate includes high-nutrient organic matter or fertilizers. Additional research is needed to investigate growing mediums which do not contribute pollutants to runoff. Part of this needed research is to examine regionally appropriate plants that might optimize the uptake of nutrients or contaminants or conversely, not require any fertilizer or high-nutrient compost. Third, in certain Texas regions, with its extended periods of intense heat and drought, it can be difficult to keep green roof vegetation alive without regular irrigation. It is important to choose regionally-appropriate plant species that can withstand drought and high air and soil temperatures found in this sub-tropical region. It is important to note that many appropriate green roof species may go dormant during the summer months and that aesthetic does not always match the desired goals of the project. Lastly, it is essential to specify the performance objectives of the roof upfront to optimize success and efficacy of the green roof system. Specifying performance goals helps to ensure that the manufacturer supplied system suits the design needs and is not simply an unspecified green roof for its own sake.

### **3.8.2 Proprietary Systems**

Currently, there are many proprietary systems on the market designed to meet stormwater management goals. Suppliers of these systems all have specific design and maintenance criteria available if this a desired option for a project site. Other TCEQ-approved proprietary systems may be used on a case-by-case basis, upon approval of the City Engineer.

#### ***Benefits***

There are many benefits to these and other systems currently on the market. First, many of these systems, like the other structural systems described above, can be custom designed for a specific project with regard to media mix and vegetation. Secondly, they can be a good choice for highly urban areas where space is limited or where retrofits to existing storm drains are desired. Lastly, they can be efficient to implement and often offer guarantees against performance and structural failure.

#### ***Limitations***

While proprietary systems have certain advantages, they also have several limitations. First, under current regulations, several proprietary systems are not allowed in certain jurisdictions or over aquifer recharge or contributing zones. Thus, it is important to investigate any local or regional regulatory obstacles that may exist which prohibit or prescribe their application. Second, these systems can be limited in their ability to address site performance goals and the regional ecological conditions to the fullest degree. Many of the proprietary systems are designed to reach certain performance targets, such volume reductions or solely filtration purposes, or a combination. If this approach is chosen, it is important to understand the various performance goals for each system to assess whether these match the performance goals of a project in New Braunfels.

### 3.8.3 Constructed Wetlands and Wet Ponds

A constructed wetland is a constructed basin that has a permanent pool of water throughout the year (or at least throughout the wet season). They differ from wet ponds primarily in that they are shallower and have greater vegetation coverage. Constructed wetlands are now used to remove point and nonpoint water pollutants from stormwater runoff as well as from domestic wastewater, agricultural wastewater, landfill leachates, and coal mine drainage among other industries. For some wastewaters, constructed wetlands are the sole treatment; for others, they are one component in a sequence of treatment processes. Constructed wetlands can be highly effective systems; however, to be effective, they must be carefully designed, constructed, operated and maintained. A distinction should be made between using a constructed wetland for stormwater management and diverting stormwater into a natural wetland. The latter practice is not recommended and in all circumstances, natural wetlands should be protected from the adverse effects of development, including impacts from increased stormwater runoff. This is especially important because natural wetlands provide stormwater and flood control benefits on a regional scale.

Wet ponds, also called stormwater ponds, retention ponds, wet extended detention ponds, differ from constructed wetlands primarily in having a greater average depth. Wet ponds treat incoming stormwater runoff by settling and biological uptake. The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological activity in the pond. Wet ponds are among the most widely used stormwater practices. While there are several different versions of the wet pond design, the most common modification is the extended detention wet pond, where storage is provided above the permanent pool in order to detain stormwater runoff and promote settling.

#### *Benefits*

- Effective pollutant removal (as mentioned in Section 2, wet ponds and constructed wetlands are two BMPs capable of achieving high TSS removal efficiencies);
- High aesthetic value;
- Habitat; and
- Recreational / amenity value if integrated into park setting (wet ponds).

#### *Limitations*

One reason these two BMPs are not included in this manual is because these systems are end-of-pipe stormwater management treatment systems and LID practices focus on on-site, distributed, at the source controls. Additionally, some issues may arise with maintaining a certain level of water within constructed wetlands and wet ponds during drought periods which can be costly to maintain or render the BMPs ineffective if the level is reduced. Please note that alternative methods to keep ponds wet from sources other than potable water are required in the City of New Braunfels. Potable water cannot be used as makeup water.